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ABSTRACT

In seeking the most effective presentation of the liberal arts in curricula such as the heavily technical and professional curricula at the U.S. Coast Guard Academy, which leave little room for general education, general education course design must capture the imagination of students and motivate them for continuing self-education. Development of an effective pedagogical approach must take into account the constraints under which students operate and the hoped for outcomes of liberal arts courses. Most importantly students must have a working concept of truth and a general framework for understanding the world and assimilating new knowledge. Teaching students to deal with the concept of truth fosters both open-mindedness and intellectual integrity. Developing courses that present a framework for knowledge is challenging, but acceptance of the fundamental assumption that all processes of human thought, imagination, and communication are ultimately physiological makes possible the construction of a simple model that includes the entire realm of the human intellect. A suggested course outline on the foundations of scholarship includes the following subjects: concepts of knowing, how people learn, the role of philosophy, levels of truth, information, input and output variables, measurement and control, cause and effect, development of disciplines, role of language, disciplinary examples, interdisciplinarity, and emergence of new disciplines. (JB)

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General Education at the Coast Guard Academy

William A. Sanders

Report 02-92

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General Education at the Coast Guard Academy

William A. Sanders
Dean of Academics

After spending twenty three years in a college of arts and sciences with a very traditional distribution-plus-concentration curriculum, I now find myself in a much different position as Dean of Academics at the Coast Guard Academy. At this institution a large percentage of the cadets major in engineering, and our core curriculum is heavily loaded with technical and professional courses. Consequently, the space left over for the humanities and social sciences is very limited. One of our most persistent curricular concerns is getting the most out of this small slice of the program that can be devoted to the "liberal arts." We don't even pretend to address the fine arts, which are relegated to the status of extracurricular (and too often purely vicarious) activities. Although we like to congratulate ourselves on the consistent success of our alumni in the best graduate schools, we can produce no comparable evidence of the quality of our general education.

My reading of the literature and many discussions with professional colleagues in other colleges have convinced me that we are not alone in our concerns. Civilian schools of engineering, business, pharmacy, nursing, and others with strong vocational orientations all share this common problem. The demands of the respective professional communities or accrediting agencies leave little discretionary margin in the curriculum for constructing a liberal general education. Given the growing appreciation for the very real value of effective liberal studies to future professionals, many of us are looking for ways to accomplish what we have long accepted as an impossibility. That is, we would like to enhance the impact of our general education courses without degrading the quality of our professional curricula. The fact that these ambitions are flourishing while so many of us lament the poor preparation of most high school graduates adds extra bite to the challenge.

This paper is an attempt to stimulate discussion on the subject of the most effective presentation of the liberal arts. It is directed to all who are concerned about quality education, but most especially those who are directly concerned with the design of the curriculum in general and the general education component in particular. The challenge is to structure our general education curricula and to design courses that capture the imagination of our students and motivate them for continuing self-education. As a catalyst for initiating the dialogue I hope will ensue, I propose an organizing principle around which a more effective pedagogical approach might be designed and implemented.

Over the past thirty years I have read about, listened to, and participated in many discussions about the philosophy and structure of the undergraduate general education curriculum. I have watched the pendulum swing between maximum curricular rigidity, on the one hand, and total flexibility with little or no structure on the other. Coherent debates of the issue are greatly complicated by the staggering increase of institutional diversity in the decades since World War II. One need only consider the enormous gulf that separates the most traditional liberal arts colleges from the host of vocational and technical colleges that occupy the other end of the spectrum. The variation of individual missions and styles between those extremes is nearly continuous. Indeed, this bewildering variety of institutions and educational missions makes a universal dialogue almost impossible. Thus we have various groups debating the content of the "canon," the nature of the major, the role of general education in professional programs, the importance of experiential learning, the nature of truth, and so on. The issues are clouded further by questions of interdisciplinarity, assessment, access, diversity, accreditation standards, natural constituencies, etc. Discussions of curricular reform are very often hampered by the constraints of resources or disciplinary structure, whether they be concerns about the protection of "turf" and faculty billets or difficulties of interfaculty communications across disciplinary boundaries.

One of the major barriers to unanimity of purpose is the fact that the construction of undergraduate curricula can be based on markedly different foundations. The underlying pedagogical principle could be philosophy of learning, information content, patterns, processes, or skills acquisition, to name a few. Any one of these could be used to provide theoretical justification for a curriculum design. However, these different and frequently divergent approaches can often engender easily recognizable stereotypes of disciplinary categories or of institutions with distinctive missions and objectives. As such they trigger reflexes that automatically activate proprietary defenses to combat the virus of interdisciplinary cooperation. In view of the bitter debates over content and process within some disciplines, it is hardly surprising that there has been so little agreement among representatives of different fields.

Admittedly each of the curriculum design principles mentioned above may be appropriate for some category of students. A talented few can absorb an education based exclusively on a study of the world's great philosophers past and present and extrapolate the insights thus acquired to their own future experiences and relationships. Others may be capable of organizing great quantities of data and constructing templates that can be superimposed upon the world revealed to them by their senses. However, the vast majority of our college students will not make these connections and generalizations on their own without significant guidance and instruction. Furthermore, they find the barriers between disciplines to be essentially impermeable. The average engineering undergraduate who takes an introductory course in psychology, for example, acquires very little competitive advantage that can be carried over into a course in international relations. Given the difficulty most faculty members experience in trying to communicate across the same boundaries, what else should we expect?

It is important to recognize that colleges of arts and sciences enjoy advantages in the construction of curricula for their own majors that are not shared by the professional schools. The absence of dominant external constraints on the curriculum creates substantial flexibility and opportunities for developing themes. It is not uncommon for the major or area of concentration to claim no more than 10 or 12 of the standard 40 courses required for a liberal arts BA degree. In a typical professional school curriculum, by contrast, major requirements and related prerequisites often preempt all but a handful of the total course requirements. At the Coast Guard Academy, for example, an engineering major may take as few as six or seven courses outside the prerequisite, major, and professional categories. This leaves little margin for error if the small number of "general education" courses is to achieve its desired impact.

What, in fact, is the desired effect of the general education component of any undergraduate curriculum? Much of the debate among the intellectual elite who are the spokespersons for the liberal arts tradition seems, from an external perspective, to be focused on the development of a common vocabulary, storehouse of facts and quotations, and catalogue of ideas. The bulk of the criticisms that reach the media use widespread ignorance of names, dates, definitions, and historical events as examples in deploring the sad state of education in this country. We are fond of joining the popular chorus and wagging our fingers at our secondary school colleagues for failing to properly educate the students they send to us. The fact remains, however, that the standard liberal arts curriculum offers an adequate opportunity to remedy most of these shortcomings in the course of a four-year college education.

If we simply try to condense a typical liberal arts curriculum into the space available in an engineering program, for example, we can create nothing more than a poor caricature of a liberal education. We will be accused of attempting to do no more than apply a thin veneer of culture, in hopes that our future engineers will not be perceived as narrow-minded cretins in cocktail party conversations with Amherst graduates. I recall a discussion some years ago with the chairman of a university history department. Having noted that their major requirements consisted only of a listing of courses with no prescribed sequence, I asked him how the undergraduates were expected

to acquire an understanding of the philosophy and methodology of history as a field of scholarly endeavor. His response was that they would eventually absorb that understanding by osmosis after having been exposed to a variety of courses and a number of different professors. Given the success of his program in placing students in quality graduate programs, I could not challenge the efficacy of that approach. However, how could it possibly succeed in an environment where most of the students take no more than one history course?

What are the essentials that undergraduates should take away with them when they complete their studies? Certainly they must have a working vocabulary that will enable them to survive in the professional world, since effective communication is critical to the success of any intellectual endeavor. In order to be at ease with themselves and their environments, they should have a sense of their heritage and their responsibilities as citizens. If they are to succeed in positions of intellectual leadership, however, they must have a working concept of truth and a general framework for understanding the world and assimilating new knowledge. These last outcomes are not automatically associated with the typical undergraduate college experience today, unfortunately, except for those students who are lucky enough to have very special mentors or to be blessed with extraordinary intelligence and insight.

The goal of teaching students to deal with the concept of truth is to foster both open mindedness and intellectual integrity. For many college students, these ideas are so abstract as to lack relevance to their personal lives. In order to stimulate these students and encourage them to value seeking the truth, college instructors at all levels must be willing to confront and examine their own truths honestly. This means doing it in front of their students and encouraging them to do the same. No "truths" should ever be announced *ex cathedra* without examining at least briefly the evidence or arguments on which they are based. Perhaps high school may still serve as a workshop where facts are accumulated and vocabulary is developed without much critical examination. However, this style of learning has no place in a college or university, no matter how vocational its mission.

The second goal, that of constructing a framework of knowledge, is much more challenging. I know of few college courses or curricula that really attempt to do this in a systematic way that is accessible to the majority of students. When it is done, it is nearly always from the viewpoint of philosophy, history, or developmental psychology, for example, and the students are immediately confronted with the barrier of the specialized vocabulary of the practitioner who attempts to reveal to them his or her epistemological insights. Disciplinary jargon and specific conventions of thought are, in fact, powerful barriers to interdisciplinary learning and thinking for professors as well as for students.

What is needed is a simplified model that can be absorbed by ordinary college students, just as Japanese school children are first taught to write in *kira-kana* before they begin to master the more complex *kanji*. It must provide a framework that embraces all or nearly all intellectual endeavor, yet it must not be dependent on mastery of specialized vocabularies. This means we must identify the common threads that run through all discovery and creative use of scholarly knowledge and introduce them in language that is as nearly discipline-neutral as possible. At the same time, it is important that students acquire an appreciation of the extent to which mastery of one or more traditional disciplines can help them add deeply rewarding superstructure and ornamentation to their basic frameworks.

That which follows is not presented as a unique model, nor as one that contains great insights. Rather, it is meant to be taken as an example of one of perhaps many possible approaches to constructing a workable interdisciplinary world-view that can be comprehended and built upon by undergraduates. It is based on making students aware of the common themes and processes encountered in all intellectual fields, and helping them understand the source and meaning of discipline-specific viewpoints. Underlying the model is one very fundamental assumption, which

may in itself betray the author's disciplinary background. This premise is that all processes of human thought, imagination, and communication are ultimately physiological. That is, creative acts are fantastically complex elaborations of fundamental atomic and molecular life processes. The purpose of making this statement is not to suggest that art appreciation may someday be taught by biochemists or elementary particle physicists, but only that it is possible in principle. In other words, it is possible to remove the mysticism from the learning process without necessarily taking away the fun. If we accept this basic assumption, then we have found a justification for constructing a simple model that includes the entire realm of the human intellect.

Almost any undergraduate is capable of understanding the concept that all modern scholarly disciplines are systematic investigations of cause and effect. In physics one predicts the acceleration that is caused by an applied force. Psychologists study reactions to stresses of various kinds. Professors of literature are concerned with the thoughts and emotions that are stimulated by ingeniously crafted sequences of words. Indeed, any activity that does not involve the generation of responses of some kind to at least partially controllable stimuli is unlikely to ever be dignified by association with an academic discipline (or, for that matter, to be rewarded with financial support). The scholarly process (avoiding the value-laden adjective "scientific") begins by identifying the independent causal variables, defining the parameters that describe the effects, and developing strategies to control the former and measure the latter. The goal of this exercise is to develop models that share these variables and parameters with the "real" world, and that represent the closest we can come to actually understanding what goes on in that world. In the present context, this means understanding the cause and effect relationship between the input and output variables. To the extent that these models are successful in mimicking the real world, their practical utility rests on the hope that they will suggest new questions or identify new variables. In the minds of many intelligent laymen, their esthetic utility is best left to be decided by philosophical debate or private contemplation. However, it is important for students to recognize that these models often represent that which we accept as our working definitions of "truth."

Why do I choose the idea of cause and effect as a fundamental principle rather than some more noble proposition? It is for the very practical reason that even the least imaginative among us can appreciate the tangible and intangible benefits of being able to manipulate variables to produce desirable effects. I believe the concept can be used to capture the interest not only of those whose ideals are most lofty and cerebral, but also of those driven by more venal motives. For many, the preexistence of some trace of curiosity should be enough to render them susceptible to the promise of understanding cause and effect.

If all disciplines are variants of the general study of cause and effect, then what is the nature of their differences and what are the sources of the interdisciplinary barriers? The differences are most easily understood, because they are due primarily to the number of input and output variables that can be identified and the certainty with which they can be controlled, measured, or predicted. These differences, incidentally, may be due to the inherent complexity of the phenomena being studied, or they may simply reflect the degree of maturity of the discipline and the sophistication of its practitioners. At one extreme, in the most rigorous branches of pure mathematics, the number of variables is small and totally controllable. The relationship between cause and effect is precisely and completely defined, and the output variables can be determined exactly. In art, by contrast, the input variables are much harder to identify and rarely susceptible to quantification. The relationship between cause and effect (for example, the reactions of a viewer or listener to a particular mode of presentation) is poorly understood and difficult to describe in concrete terms.

No worthwhile scholarship takes place in a vacuum. In order for an expansion of knowledge to occur, scholars must communicate with one another. This requires that they develop a vocabulary with which they can describe their observations, insights, and models. However, the incredibly broad range of phenomena that are subject to scholarly enquiry requires a vocabulary much too large to be mastered by a single individual. Thus many, many "languages" and "local

dialects" have developed in response to the universal need to communicate. The vocabularies, grammar, and syntax of these languages vary in relation to the complexity and maturity of the field. The language of mathematics, for example, consists of a relatively small vocabulary of words whose meanings are both rich and precise. Sentence structure is critically important, and ideas can be expressed with impressive economy of words. On the other hand, the vocabulary of painting includes many words and phrases whose meanings are vague and subjective. Variations in syntax may themselves become vehicles for richer communications.

For convenience, let us define a "discipline" as a group of scholars who speak the same language. Subdisciplines are then smaller groups who share a common local dialect. We may use the same terms to describe the sets of phenomena that form the subjects of communications in these languages and dialects. Unfortunately, the very languages that are developed to facilitate communications within disciplines or subdisciplines become barriers to communications among disciplines. Languages are defined for the purpose of describing and discussing families of phenomena that generally share similar numbers and types of variables and related cause and effect patterns. Inevitably these vocabularies lose their utility as they are applied to situations further and further from the central problems from which they developed. Thus the limits of a discipline can be defined as the useful range of its vocabulary.

To relate this concept back to our earlier discussion, we might also think of disciplines in terms of shared models or conceptual frameworks. The practical and developmental value of models is well understood by all scholars. They often enable us to construct very rich images on the basis of sparse data fields. They may suggest analogies and relationships that are not obvious from an exclusively empirical examination of raw information. At the same time, we are well aware of the limitations on our creativity that result from exclusive reliance on models that are too rigid and circumscribed. In language terms we would say that our horizons are severely limited if we remain forever monolingual.

Many of the great advances in human understanding have been made by individuals who were scholastically multilingual. That is, they were partially conversant in languages or dialects of fields other than their own. They were able to think about and describe the same phenomena in different vocabularies, and this often opened fresh viewpoints that led to breakthroughs in understanding. It is important, therefore, that scholars strive to become multilingual in this sense. That is, they should learn to speak the languages of colleagues in distinct but related fields as a first step toward achieving a unified view of human knowledge. Obviously it is easiest to begin with phenomena for which two adjacent disciplines have vocabulary in common. An almost trivial example is the case of the Spanish literary scholar who may, by studying Italian, gain fresh insights in spite of the closeness of the fields.

The Spanish scholar learns Italian easily for two important reasons. First, the vocabularies are very similar, sharing many identical or easily recognizable cognates. This greatly facilitates the task of constructing a mental data base of adequate scope to make progress in the new language possible. Whole subsets of vocabulary can often be transposed mentally by the application of simple conversion algorithms, thus eliminating the need to create extensive new data storage areas. Second, the basic structures of the two languages are very similar, so that one who is literate in Spanish has a preexisting model that can be copied into another area of main memory. There it can supervise the more rapid and efficient loading of Italian into the brain.

Now suppose the Spanish scholar wishes to learn German. The ease of this task will depend very much on how well he or she understands the basic linguistic principles of the Indo-European languages and their common word roots. Extending the argument a step further, facile mastery of Japanese by the same individual must depend on the possession of an even more general model of human language structures. Perhaps the ultimate of this extrapolation process might be attempting

to communicate with other species on Earth. Achieving such a goal would be inconceivable without a very broad and sophisticated model of basic communication processes.

Surely a Spanish professor who fails to point out to his or her students the relationships between the vocabulary and structure of Spanish and those of other romance languages, at the very least, misses a golden opportunity to help them lay priceless foundations for more efficient future learning. Likewise a history professor should emphasize the vocabulary and methods the discipline shares with other social sciences. This basic framework building is especially critical at the lower undergraduate level, when many students have only vague ideas of where their intellectual futures may lead them.

What are the curricular implications of this approach? In an enlightened undergraduate program, every instructor might take pains to identify and illuminate the links of the discipline to all others. Common vocabulary could be identified, and methods could be related to general models spanning a number of disciplines. A student who took courses in a rather broad selection of disciplines might, at the end of the undergraduate experience, have synthesized an acceptable appreciation of the unity of the intellectual disciplines.

There are several flaws in this picture, however. In the first place, it assumes viewpoints and attitudes on the part of faculty that probably do not exist at most colleges or universities. It certainly is an unfair expectation of the junior military instructors at the Coast Guard Academy. Second, discussing the same or similar kinds of relationships in successive courses in the same discipline would lead to extensive redundancy and sacrifice of subject matter content. Finally, students in many professional curricula simply don't take enough courses in the social sciences and humanities to be able to synthesize an adequate general model of knowledge in such a piecemeal manner. Given that this category of students currently comprises a very large fraction of undergraduate populations, the problem is of national proportions. It is safe to assume, in fact, that a majority of college graduates complete their formal educational experience without having acquired a comprehensive and satisfying grasp of the overall structure and significance of the liberal arts.

Faculty in professional and vocational colleges have long been aware and concerned about this limitation of their programs. There have been numerous sincere attempts to remedy what is commonly accepted as a disadvantage of too narrowly career-oriented education. Most of these efforts have concentrated on one of two alternatives. The first is to find ways to increase the general educational content of the curriculum. This approach runs immediately into the barrier of disciplinary requirements, often specified by external accrediting bodies or marketplace pressure. With the exception of the few institutions that enjoy sufficient prestige to market five-year programs, therefore, there is generally little the faculties can do to increase the number of general education courses in their curricula. The other common approach is to agonize over the choice of the limited number of general education courses to be offered to students in professional majors. This leads to endless and almost never satisfying debates that are often fatally marred by considerations of resources, disciplinary prerogatives, and protection of "turf."

A third alternative is to design an introductory course whose declared purpose is to explore the general process of acquiring, interpreting, and exploiting knowledge in any field. Such a course would differ from those of the "Western Civilization" genre required at many liberal arts colleges, in that it would concentrate on building general frameworks of learning instead of accumulating a basic dictionary of facts and concepts. The new course need not replace Western Civilization or World Culture, but in fact should be a valuable complement if we were to decide to offer such a traditional survey as a followup.

To be more specific, let me outline my concept of what the syllabus of the new course might look like:

Foundations of Scholarship

The concepts of "Knowing" and "Understanding"

How people learn

The special role of philosophy

Levels of truth

Information

Input and output variables

Measurement and control

Cause and effect

The development of disciplines
- Collection of data
- Organization of information
- Construction and refinement of models
- Extrapolation into the unknown

The role of language

Disciplinary examples
- Mathematics
- Biology
- History
- Art

Interdisciplinarity

The emergence of new disciplines

Summary

Perhaps the greatest challenge to the introduction of a course such as this is the question of who should teach it. Clearly it requires faculty members who themselves have a very broad grasp of human scholarship. The disciplinary representatives who participate must be "multilingual" in the sense defined above, so they can discuss the relational concepts that tie their individual fields together. The course must be distinctly different from many so-called "interdisciplinary" courses that consist of a parade of faculty members from two or more disciplines who take turns lecturing to the students from the viewpoints of their individual fields. There must be dialogues in the presence of the students, and they must emphasize the unity of knowledge instead of disciplinary differences.

Let me now discuss each of the topics in my suggested course outline in more detail. I would begin by encouraging the students to explore their concepts of what it means to know something or to understand a phenomenon. The discussion should cover such questions as where facts come from, how we decide if they are reliable, the role of intellectual authority, the concepts of right and wrong, etc. At this point the goal is to start the students thinking critically, if naively, about the

nature of knowledge. They should be encouraged to be curious and to be skeptical of statements of fact offered without supporting evidence. It is a great tragedy that so many adults have so little patience with the "why" questions of childhood. In too many cases, genuine intellectual curiosity has been socialized out of young people by the time they get to college. Specific disciplinary language or references should be avoided, except for purposes of illustration. It is more important to connect to the students' own prior experience so they can approach this course by building on (and perhaps remodeling) their preexisting frameworks of understanding.

There is growing evidence that students learn more efficiently if they have a basic understanding of the learning process itself. Serious consideration should be given to the idea of devoting some time at this early point in the course to a discussion of a model of intellectual development. Personally I am partial to the levels of Perry,[1] but I believe any comparable framework that helps the students understand their own thinking and questioning processes can accomplish the same purpose. Another popular model, for example, is Bloom's taxonomy.[2] The idea is to start them thinking about how they react to new information and how they can tell if they are making intellectual progress.

It would be quite inappropriate, I believe, to undertake an academic course which purports to lay a foundation for studying any discipline without acknowledging the special role of philosophy. One or two periods should be devoted to a discussion of what philosophy is and what its impact has been on human thought and on other scholarly disciplines. Students should, at the very least, be aware that there are carefully developed rules of logic and analysis. More ambitiously, it can be hoped that some will come to view thinking as a skill that is susceptible to improvement through informed practice. The temptation to encapsulate the history of philosophy should certainly be avoided. Instead, a handful of the most influential thinkers could be mentioned, along with the significance of their key contributions.

A discussion of the meaning of "truth" is important to ensure that the students have a healthy and skeptical appreciation for both the power and the limitations of the concept. It is important that they examine accepted truths and think about whether they are absolute or only relative or conditional. What are the roles of experimental or observational evidence, and is there a place for "faith?" They should be led to think about constructing tests for truth, even if only in very crude forms. Every student who completes this course should come out with an appreciation of what is expressed and implied by the uttering of a dogmatic statement.

Young people are bombarded daily by messages that trumpet the importance of information in the modern age. They need to understand just what information is and why it attracts so much attention and investment. The course coverage should include both the historical development and modern concepts of the value and utilization of information. There should be a basic understanding of the significance and utility of the manipulation, storage, and retrieval of data. Students should also appreciate the importance of knowing how to acquire, evaluate, prioritize, and safeguard information.

First-year college students can be expected to arrive with a wide range of sophistication in their understanding of the idea of a "variable." Accordingly, the instructor will need to spend some time making sure all of the class understands the concept and its significance. Numerous and varied examples should be drawn from contexts that are familiar to the students by virtue of their prior experience. In this respect, it is important not to overlook the significance of ethnic or gender differences in selecting and constructing examples that are intended to be both familiar and instructive.

The act of measurement should be discussed in a general way, using a range of examples from the hard sciences to the humanities. Concepts of statistical variation, uncertainty, precision, and

accuracy should be defined. Measurement and control of variables should be related to such practical topics as experimental design, production quality control, marketing and salesmanship, politics, etc. In this and other discussions the instructor should not neglect to identify specific courses in the college curriculum that offer opportunities for further study of topics mentioned in this course.

Since cause and effect was assumed to be the central motivating principle of this course, it must be presented in an interesting and provocative manner. Numerous examples should be mentioned, and they should cover the full range from strictly deterministic mathematics to the most subjective arts. It is essential that the students buy into the concept that understanding cause and effect is a key to personal power and influence. Some instructors may wish to juxtapose examples of both constructive and antisocial manipulations of cause and effect as a way to remind the students that the study of ethics has genuine value.

A discussion of the generic stages of development which all mature disciplines have undergone is a critically important prerequisite to any attempt to compare disciplines and establish common threads. It would be helpful in the process to identify actual disciplines that are currently in or have recently emerged from each of the four stages.

The importance of language should be self evident to anyone undertaking the teaching of this course. It would be helpful to cite examples of different meanings of the same words or symbols, and the confusion that can result by the use of language that is not common to the transmitter and receiver of information. I still recall a futile argument many years ago with the Russian professor who administered my graduate reading exam. The range of meanings he attached to the simple word "field" clearly did not extend into the realm of theoretical physics which was, unfortunately, the subject of the article I was assigned to translate. Equally important is to discuss the power of language in creating images and impressions that may either stimulate or restrict creative thinking.

Three or four popular disciplines should be reviewed by the principal lecturer (if he or she is brave enough) or by disciplinary representatives who understand and are sympathetic with the underlying thesis of the course. The students should be expected to think about and identify the common themes, as well as the differences in stage of development, number of variables, degree of causality, etc. It is my personal feeling that it is important to cite specific examples to emphasize commonalities of intellectual approach in disparate fields. By way of illustration, I describe in the Appendix a comparison of research methodologies in two quite different fields. The examples and accompanying descriptions are admittedly oversimplified and idealized, but I believe they serve to make my point.

There is great potential excitement in this kind of comparative analysis when scholars in different disciplines are able to discover the analogies in their approaches to the creation of knowledge. Our respect and appreciation for the intellectual accomplishments of colleagues in other fields cannot fail to be enhanced when we realize that they are applying the same reasoning skills we value in ourselves. If these discoveries are made or reenacted in the presence of students, they can be transformed into great moments in intellectual development.

The concept of interdisciplinarity is perhaps best illustrated by discussing a few specific examples, such as biochemistry, comparative literature, or art education. Important topics should include a discussion of factors that give rise to interdisciplinary fields and the development of language by the coining of new words or extension of the meaning of existing words. The students should be invited to think about how an interdisciplinary field might evolve into a full-fledged discipline. Points of discussion could include the creation of journals and professional societies, the development and institutionalization of unique dialects, growing isolation from the parent disciplines as a result of increasingly frequent and exclusive association with those of similar interests, etc.

In the summary, the lecturer should review not only the coverage, but also the chief motivation for the course. It is important that the students understand why they have been required to take the course and what they were expected to get out of it. They should be given a number of suggestions for future study and for helping them select other courses in the general education component of their curriculum. Finally, it is absolutely essential that they be asked to share their reactions to the course and to assess the perceived value they have derived from it.

My proposal can (and no doubt will) be criticized for neglecting the esthetic dimension of the liberal arts. I accept the point, but plunge ahead in spite of it. It has been my experience that many pragmatically oriented students have difficulty appreciating the beauty of that which they do not understand or respect. I believe that if we build a conceptual base which technical students can use to relate the humanities and social sciences to their own interests and methodologies, further study and eventual esthetic appreciation will follow. Many of us who began the study of particular subjects for the most sterile and pragmatic reasons eventually came to appreciate their esthetic dimensions. I would also point out that a sensitive and exciting teacher can help students realize the inherent beauty of the subject they are studying. Although it is uncomfortable to admit, we all recognize that an uninspired teacher can rob even a course in art appreciation of much of its esthetic appeal.

Appendix

My first example is taken from the field of chemistry, simply because it happens to be my own professional specialty. Suppose a chemist is interested in understanding and predicting the temperature dependence of some measurable chemical phenomenon. Temperature is a common variable in many chemical problems. The phenomenon of interest might be the rate of a chemical reaction, the viscosity of a fluid, or any one of many such measurables. Our investigator might begin by performing measurements (observations) at, say, 300 and 500 degrees. He or she would then attempt to construct a mathematical or descriptive model that is constrained to reproduce the measurements at 300 and 500 degrees. In constructing the model, the chemist will call upon a cumulative store of information and insights about the fundamental processes that determine the behavior of the effect being investigated. The model itself will be described in a language that is peculiar to the discipline, with references to forces, energy levels, electron distributions, etc. Quite likely the process will involve the synthesis of existing models that describe simpler components of the complex behavior being studied. Our point is, however, that although the process will differ widely in detail depending upon the discipline, it can be described in all cases by words such as "building a model" or "constructing a theory."

The model can be tested by using it to predict the outcome of a measurement of the same phenomenon at the intermediate temperature of 400 degrees. Our chemist then performs a measurement at that temperature and compares it with the value predicted by the model. If the two values agree very closely, the model is judged to describe the physical phenomenon adequately at this level of detail (100 degree increments). On the other hand, it is more likely that the measured and predicted values at 400 degrees will differ substantially. The investigator must then return to the model and refine it, generally by making it more complex and sophisticated. New predictions of revised models are followed by new measurements until the agreement between the two satisfies the criteria established by the chemist (or by the professional peer group). This process can be continued by repeating the measure and model cycles at smaller and smaller temperature intervals. Sooner or later, however, reality induces the investigator to declare either that the model has attained adequate descriptive power over the temperature range of interest or that the point of diminishing returns has been reached.

The next step is to explore the predictive powers of the model at temperatures above or below the original range. This extrapolation procedure imposes a more stringent test on the ability of the

model to mimic the real physical phenomenon. Comparison of predicted and measured values may set off a new cycle of model refinement until the practical possibilities are exhausted or the scientist's curiosity is temporarily satisfied. The most exciting prospect is that investigations of the source of disagreement between extrapolated predictions and real measurements occasionally lead to important new discoveries.

Now let us shift our attention to a hypothetical military historian who is interested in reconstructing the route followed by a small raiding party known to have penetrated into enemy territory during a minor European war. As in the case of the chemist, we will not question the historian's motives for wishing to understand and describe this phenomenon. We will begin by supposing that the scholar is in possession of data showing conclusively that the raiding party passed through town A on April 23 of that year and arrived at town C on May 17. Nothing more is known about the group's movements, however, nor is their military objective obvious.

Our historian might begin by attempting to construct a model of the route actually followed from town A to town C. The information used to construct the model might include, for example, the topography of the area, location of roads, availability of food and water, standard tactical doctrine in effect at the time, disposition of enemy troops, etc. Now let us assume that the model thus constructed predicts that the raiding party should have been at town B on or about May 2. The historian can proceed to look through libraries, correspondence, town archives, archeological records, or other sources for evidence that the group did indeed pass through town B on or about that date. If no such evidence can be found, it may be necessary to revise the model by constructing alternate routes and seeking data elsewhere. If the prediction can be proven correct, then the researcher can proceed to postulate and eventually verify the whereabouts of the raiding party on, say, April 28. This iterative procedure can be continued until, hopefully, the entire route from April 23 to May 17 is mapped out in sufficient detail. Just as in the case of the chemical example, the definition of "sufficient detail" may depend on a variety of factors either internal or external to the investigator.

Although the scenario is much more complex and perhaps more problematical than the chemical example, the underlying intellectual reasoning is basically the same in both cases. To complete the analogy, we need only challenge the historian to push ahead and predict the further route of the detachment through May 26. It is this extrapolation process, in fact, that is the ultimate goal of the scholarly exercise. For the chemist, the true motivation may be to predict the behavior of the phenomenon of interest in a temperature range that is not experimentally accessible. Such an extrapolation can be done with confidence only if the behavior of the system inside the experimental range can be modeled faithfully. An analogy for the historian might be that the raiding party was intercepted and destroyed before it reached its military objective. The only way to speculate on what that objective might have been, then, is to perform an extrapolation based on the reconstructed behavior of the group before it ceased to exist.

It is my suggestion that by exploiting comparisons of this kind, with examples chosen both from fields the students already respect and from those we would like them to accept, we can induce them to want to expand their intellectual horizons in directions they would otherwise resist.

References

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